Delayed open conversions after endovascular abdominal aortic aneurysm repair

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Objective: **Secondary interventions after endovascular aneurysm repair (EVAR) remain a concern. Most are simple catheter-based procedures, but in some instances, open conversions (OCs) are required and carry a worse outcome. We reviewed our experience to characterize these OCs.**
Methods: **A retrospective review was conducted of all patients who underwent an OC after a previous EVAR for an aneurysm-related indication from 2001 to 2010. Clinical outcomes are reported.**
Results: **Data were reviewed for 44 patients (77% men) with a mean age of 74 years (range, 55-90 years). The average time from EVAR to the first OC was 45 months (range, 2-190 months). In six patients (14%), the initial EVAR was at another institution. The endografts used were Ancure in 16, Excluder in 13, AneuRx in eight, Zenith in three, Lifepath in one, Renu in one, and undetermined in two. Twenty-two patients had previously undergone a total of 32 endovascular reinterventions before their index OC. Indications for OC were aneurysm expansion in 28 (64%), rupture in 12 (27%), and infection in four (9%). The endograft was preserved in situ in 10 patients (23%). Explantation was partial in 18 (41%) or complete in 16 (36%). Endograft preservation was used for type II endoleak in all but one patient by selective ligation of the culprit arteries (lumbar in four, inferior mesenteric artery in five, and middle sacral in one). Proximal neck banding was performed in one type Ia endoleak. Overall morbidity was 55%, and mortality was 18%. No deaths occurred in a subgroup of patients who underwent endograft preservation with selective ligation of culprit vessels for type II endoleak. Intraoperative complications included bowel injury in two, bleeding in two, splenectomy in one, and ureteral injury in one. At a mean follow-up of 20 months, two patients underwent additional procedures after the index OC: one after endograft preservation and one after partial explantation. None of the patients who underwent elective OC with endograft preservation required subsequent endograft explantation.**
Conclusions: **Most OCs after EVAR are associated with significant morbidity and mortality, except when electively treating an isolated type II endoleak with ligation of branches and preservation of the endograft. (J Vasc Surg 2012;55: 1562-9.)**

Endovascular aneurysm repair (EVAR) has become the preferred treatment for infrarenal abdominal aortic aneurysms (AAA). Currently, ~60% of infrarenal AAAs are treated by endovascular means. This is due to superior short-term outcomes with EVAR compared with open repair.[1-3] However, long-term surveillance with timely reintervention, when indicated, is critical to ensure long-term success.

Even though most reinterventions after EVAR are performed by endovascular means, a small proportion of patients (0.9% to 4.5%) will require an open intervention.[4-8] The results of open conversions (OCs) for aneurysm repair after EVAR are limited to case series, and comparison of outcomes is difficult due to heterogeneous indications and treatment strategies. This study reports a single center's experience with delayed (>30 days) OC after EVAR.

METHODS

Medical records of patients who underwent delayed OC after EVAR at the University of Pittsburgh Medical Center (UPMC) and the Department of Veterans Affairs Pittsburgh Healthcare System (VAPHS) during a 10-year period between January 2001 and December 2010 were reviewed. Institutional Review Board approval was obtained from both institutions.

OC was defined as any transperitoneal or retroperitoneal intervention for aneurysm-related or graft-related complications, with or without endograft explantation. Only delayed OCs that were performed >30 days of the index EVAR were included in this study. The techniques used included total or partial explantation of the endograft, complete preservation of the endograft with ligation of culprit arterial branches accountable for the endoleak, and aortic neck banding.

Patient demographics and comorbidities were noted. The indications and the operative reports of the initial EVAR, when available, were reviewed. Patients were monitored at 1 and 6 months after EVAR and then yearly. More frequent follow-up was at the discretion of the operating

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Table I. Baseline patient characteristics undergoing elective and nonelective open conversions

Variables[a]	*Total*	*Elective*	*Nonelective*	P
Total patients	44	19 (43)	25 (57)	
Age, years	74 ± 8	75	73	.66
Male sex	34 (77)	16 (84)	18 (72)	.47
Comorbidities				
Hypertension	40 (91)	17 (90)	23 (92)	>.99
Hyperlipidemia	25 (57)	11 (58)	14 (56)	>.99
Diabetes	9 (20)	5 (26)	4 (16)	.47
Coronary artery disease	23 (52)	9 (47)	14 (56)	.76
CABG	12 (27)	5 (26)	7 (28)	>.99
Renal insufficiency	6 (14)	2 (10)	4 (16)	.68
Cerebrovascular disease	7 (16)	4 (21)	3 (12)	.44
COPD	13(30)	5 (26)	8 (32)	.75
Smoking	24(54)	10 (53)	14 (56)	.29
Medications				
β-Blocker	30 (68)	13 (68)	17 (68)	>.99
Statin	22 (50)	11 (58)	11 (44)	.54

CABG, Coronary artery bypass grafting; *COPD,* chronic obstructive pulmonary disease.
[a]Data are presented as number (%), except for age, which is mean ± standard deviation.

surgeon. Clinic notes and imaging studies were reviewed for secondary interventions after EVAR.

Before OC was performed, an endovascular approach was attempted first to treat patients with asymptomatic aneurysm growth and in select cases of rupture. When endovascular means failed, the decision to proceed with OC was based on the risks of an OC weighed against the risks of rupture, depending on the size of the aneurysm and the type of endoleak. In general, a type I endoleak was treated when identified regardless of aneurysm size and a type II endoleak when associated with continued aneurysm growth >6 cm. The decision to convert was individualized in each case after careful assessment of the patient's clinical picture and overall risks.

The indications for OC were divided into three categories: aneurysm growth, rupture, and infection. OCs performed for asymptomatic aneurysm growth were performed electively. The OCs performed for rupture, infection, including fistula, and symptomatic aneurysm expansion were performed urgently or emergently and classified as nonelective OCs.

Operative details, including surgical approach (transperitoneal or retroperitoneal), operative time, cross-clamp site, estimated blood loss, and mode of reconstruction, were recorded. The type of endoleak found on follow-up or detected at OC was noted to elucidate the mechanism of failure. Intraoperative and postoperative complications were recorded. Operative mortality was defined as death if ≤30 days or in-hospital death if >30 days. Survival data were obtained from medical records and the Social Security Death Index. Results are expressed as mean ± standard deviation for continuous data and as frequency and percentage for categorical data.

The outcomes for patients who underwent elective OCs were compared with patients who had nonelective OCs. Baseline patient characteristics were compared using the *t*-test or Wilcoxon rank sum test for quantitative variables between two groups and analysis of variance *F* test or Kruskal-Wallis rank sum test for comparisons among more than two groups. The Fisher exact test was used for comparison of categorical baseline characteristics. Survival rates were calculated using the Kaplan-Meier method, using log-rank test for comparison of Kaplan-Meier curves. Analyses were performed with the R 2.11.1 statistical software (http://www.r-project.org) under the significance level of 0.05.

RESULTS

The cohort undergoing delayed OCs after EVAR comprised 44 patients (77% men) who were a mean age of 74 years (range, 55-90 years). Patient demographics and comorbidities are detailed in Table I. Average time from EVAR to OC was 45 months (range, 2-190 months). OCs in 14 patients (32%) took place ≥5 years after EVAR. Ten of these patients had had regular surveillance with detection of and treatment for an endoleak(s) in eight; in four of these, endoleak appeared >5 years of follow-up.

The endografts that had been implanted were Ancure (Guidant, Menlo Park, Calif) in 16, Excluder (W. L. Gore & Associates, Flagstaff, Ariz) in 13, AneuRx (Medtronic, Santa Rosa, Calif) in eight, Zenith (Cook, Bloomington, Ind) in three, Renu (Cook) in one, and Lifepath (Edwards Lifesciences, Irvine, Calif) in one. The endografts were undetermined in two patients.

The index EVAR had been performed at UPMC in 34 patients, at VAPHS in four, and at another hospital in six. During the study period, 1549 EVARs were performed at UPMC and 133 at VAPHS. The estimated (considering those lost to follow-up as well as those whose EVAR was performed elsewhere) overall OC rate was 2.6% (2.6% at UPMC and 3.0% at VAPHS). The actual OC rates have been relatively stable during the past 8 years, whereas the absolute number of OCs appears to have increased during the same period, as shown in Fig 1.

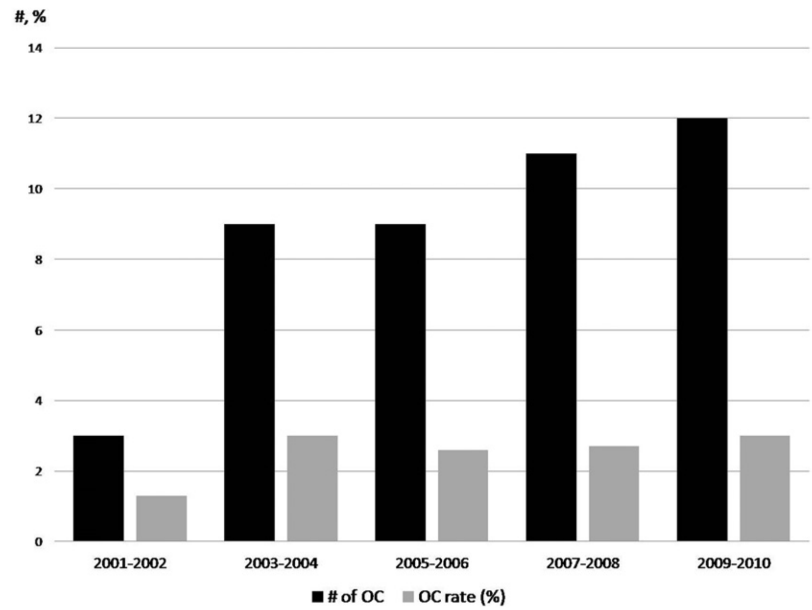


Fig 1. The number of open conversions (*OC*) performed over a decade. The OC rate was calculated as a percentage of total endovascular aneurysm repairs (EVARs) performed during a 2-year period as follows: OC rate = number of OC/total number of EVARs.

The mean diameter of the aneurysms was 62 ± 16 mm at the time of OC compared with 57 ± 11 mm at the index EVAR. All except one were done electively. The lone nonelective EVAR was for a ruptured AAA (RAAA). A type II endoleak emanating from a lumbar artery was detected on computed tomography (CT) scan at the 1-month follow-up. The patient presented 5 months later with localized rupture related to a type Ib endoleak and was treated with endovascular extension of the left iliac limb. He returned 3 weeks later with sepsis secondary to an aortoenteric fistula and underwent complete explantation of an Excluder endograft and reconstruction with an axillo-bifemoral bypass. Six patients who underwent EVAR at our institution failed to follow-up and underwent OC for rupture (n = 3) and symptomatic aneurysm expansion (n = 3).

Indications

The indications for OC in the 44 patients were aneurysm growth in 28 (64%), rupture in 12 (27%), and infection in four (9%; Table II); of these, 25 (57%) required an urgent or emergency OC. There was no difference in demographics or comorbidities between those who underwent OC under elective vs nonelective settings (Table I). All elective OCs were performed for asymptomatic aneurysm sac expansion. The most common mechanism of failure was type II endoleak in 18 (41%), followed by type I endoleak in 15 (34%). A type I endoleak in five patients was associated with endograft migration (three AneuRx, one Ancure, and one Excluder).

Endovascular reintervention before OC

Twenty-two patients (50%) had had a total of 32 endovascular interventions during follow-up before requiring OC. The indications for reintervention were type II endoleak in 15, type I endoleak in 14, and types I and II endoleak in two. The endovascular reinterventions were not successful in treating the culprit lesion in 15 patients. The reasons for failure included failure to identify the lesion, inaccessibility of high lumbar arteries, excessive iliac tortuosity, and proximal neck dilatation preventing an adequate seal. Reinterventions were successful in the remaining seven patients; however, the patients presented with another endoleak or expansion without a clear etiology. Of note, 4 of 12 patients who presented with RAAA had a history of endovascular reinterventions.

Operative techniques

Surgical approach. A transperitoneal approach was used in 98% of cases. Only one patient had a retroperitoneal exposure. He had a partial explantation of a Renu endograft for rupture.

Clamp site. Supraceliac aortic control was used in nine patients, suprarenal in 20, and infrarenal in seven. Mean renal ischemia time was 28 ± 7 minutes. Aortic cross-clamping was not used in eight patients who were treated with complete endograft preservation.

Endograft explantation with reconstruction. Complete endograft explantation was ultimately performed in 16 patients (36%): four had graft infections, of which three

Table II. Operative data stratified by urgency, indication, and endograft management

Urgency	*Elective*		*Nonelective*			
Indication	*Aneurysm growth (19)*		*Aneurysm growth (9)*		*Rupture (12)*	*Infection (4)*
Endograft management	Explantation (12)	Preservation (7)	Explantation (6)	Preservation (3)	Explantation (12)	Explantation (4)
Endograft type	Ancure (2) AneuRx (3) Excluder (6) Zenith (1)	Ancure (4) AneuRx (1) Excluder (1) Lifepath (1)	Ancure (1) AneuRx (2) Excluder (1) Zenith (2)	Excluder (3)	Ancure (7) AneuRx (2) Excluder (1) Renu (1) Unknown (1)	Ancure (2) Excluder (2)
Time: EVAR to OC, mean ± SD, months	50 ± 29	46 ± 29	46 ± 39	43 ± 31	47 ± 54	21 ± 22
Prior endovascular procedures[a]	8 (11)	6 (9)	1 (2)	1 (1)	4 (7)	2 (2)
Aortic clamp site	Suprarenal (9) Infrarenal (3)	Supraceliac (2) No clamping (5)	Supraceliac (2) Suprarenal (3) Infrarenal (1)	No clamping (3)	Supraceliac (4) Suprarenal (5) Infrarenal (3)	Supraceliac (1) Suprarenal (3)
Mechanism of failure[b]	Type I EL (4) Type II EL (6) Type V EL (1) Undetermined (1)	Type I EL (1) Type II EL (6)	Type I EL (5) Type II EL (1)	Type II EL (3)	Type I EL (6) Type II EL (2) Type III EL (2) Undetermined (3) AEF (1)	AEF (3); infection (1)

AEF, Aortoenteric fistula; *EL,* endoleak; *OC,* open conversion.
[a]Number of patients (number of endovascular procedures).
[b]A patient may have more than one type of endoleak.

were due to aortoenteric fistulas, five patients presented with RAAA, and seven had growing aneurysm sac.

An additional 18 patients were treated with partial endograft explantation. The endograft components left behind in 10 patients were most commonly the iliac stents only. In five patients, the iliac limbs and the proximal aortic struts or suprarenal stents were left behind. In two patients the iliac limbs were completely removed, with the proximal leading edge of the endograft left in situ. In the remaining two patients, only an iliac limb was removed and surgically replaced. The indications for intervention were rupture in seven and aneurysm sac expansion in 11.

Reconstruction with an aortoiliac bifurcated graft was the most common method, used in 23 patients, followed by a tube graft in six. Three patients underwent axillobifemoral bypass grafting for aortic infection, followed by complete explantation and ligation of the aortic stump. In one patient, the left iliac limb of the endograft was replaced with an 8-mm Dacron interposition graft. One patient who presented with a rupture died in the operating room before reconstruction could be attempted.

Complete endograft preservation. Ten patients (23%) were treated with complete endograft preservation. This was achieved by selective ligation of the culprit arteries causing a type II endoleak: lumbar artery (n = 4), inferior mesenteric artery (n = 5), and middle sacral artery (n = 1). One patient underwent proximal neck banding for a type Ia endoleak related to a short, angulated neck with reverse funnel configuration. The aneurysm sac was opened to document absence of flow around the endograft. The wall of the aneurysm was imbricated to obliterate potential space around the endograft. He was well, without any subsequent graft-related complications, on a 14-month follow-up CT.

Morbidity and mortality

The overall morbidity was 55%. The most common complication in the 44 patients was acute renal failure in 10 (23%); followed by pneumonia in nine (20%); bleeding in nine (20%); myocardial infarction, urinary tract infection, wound infection, or *Clostridium difficile* colitis in two patients (5%) each; and deep vein thrombosis or femoral pseudoaneurysm in one patient (2%) each. Only two patients (5%) required hemodialysis. The other complication was a sigmoid perforation 16 days after partial explantation of a Zenith endograft.

Intraoperative complications during OC occurred in six patients, including bowel injury, splenectomy, ureteral injury, or thrombosis of lower extremity bypass graft in one patient each, and bleeding in two patients. Eight patients (18%) required a return to the operating room, two for bleeding and one patient each for bowel ischemia, ureteral injury, compartment syndrome, thrombosis, femoral pseudoaneurysm, or sigmoid perforation. The mean hospital length of stay was 13 ± 11 days.

Operative mortality was 18% (8 of 44), including one intraoperative death (Table III). Table IV details the morbidity and mortality stratified according to the treatment indication and the technique used. There was a trend toward higher morbidity with nonelective OCs compared with elective OCs (64% vs 47%; $P = .36$). A higher inci-

Table III. Complications of patients with operative mortality

Pt	*Indication*	*Technique used*	*EG type*	*Complications*
1	Aneurysm growth	Complete explantation	AneuRx	ARF, thrombosis of leg requiring return to OR for LE bypass, persistent sepsis
2	Aneurysm growth	Partial explantation	Zenith	DVT, return to OR for sigmoid perforation, ARF
3	Rupture	Complete explantation	Ancure	ARF requiring hemodialysis, pneumonia, return to OR for abdominal compartment syndrome
4	Infection	Complete explantation	Ancure	ARF, return to OR for attempted ureteral stent placement after injury to the ureter
5	Aneurysm growth	Partial explantation	AneuRx	Pneumonia, ARF, severe *Clostridium difficile* colitis, persistent sepsis
6	Rupture	Preservation	Ancure	Pneumonia, return to OR for bleeding five times, small-bowel injury, open abdomen closed with Vicryl mesh
7	Rupture	Partial explantation	Renu	Thrombosis of bilateral LE bypass grafts requiring thrombectomy, persistent post-op bleeding and sepsis
8	Rupture	Intended complete explantation	Excluder	Intraoperative death due to hemorrhage

ARF, Acute renal failure; *DVT,* deep vein thrombosis; *EG,* endograft; *LE,* lower extremity; *OR* operating room.

Table IV. Morbidity, mortality, and survival stratified according to urgency, indication, and surgical technique[a]

Urgency	*Elective*		*Nonelective*			
Indication	*Aneurysm growth (19)*		*Aneurysm growth (9)*		*Rupture (12)*	*Infection (4)*
EG management	Explantation (12)	Preservation (7)	Explantation (6)	Preservation (3)	Explantation (12)	Explantation (4)
Complications	Bleeding (2) Wound infection (1) Pneumonia (2) UTI (1) MI (1) ARF (2) *C diff* colitis (1)	Bleeding (1) Pneumonia (1)	Pneumonia (2) UTI (1) LE thromb (1) ARF (2) Sigmoid perf (1) Return to OR (2)	None	Bleeding (6) Pneumonia (6) UTI (1) Femoral PA (1) MI (1) Wound infection (1) ARF (5) New HD (3) Return to OR (5)	ARF (1) *C diff* colitis (1) Return to OR (1)
Morbidity	67 (8)	14 (1)	50 (3)	0	92 (11)	50 (2)
Mortality	8 (1)	0	33 (2)	0	33 (4)	25 (1)
LOS, days	11 ± 10	7 ± 6	10 ± 6	8 ± 2	16 ± 14	19 ± 16
Survival, mon	24 ± 22	30 ± 23	23 ± 33	18 ± 12	6 ± 12	24 ± 40

ARF, Acute renal failure; *C diff, Clostridium difficile*; *EG,* endograft; *HD,* hemodialysis; *LE,* lower extremity; *LOS,* length of stay; *MI,* myocardial infarction; *OR,* operating room; *PA,* pseudoaneurysm; *UTI,* urinary tract infection.
[a]Categorical data are presented as (number) or percentage (number); continuous data are mean ± standard deviation.

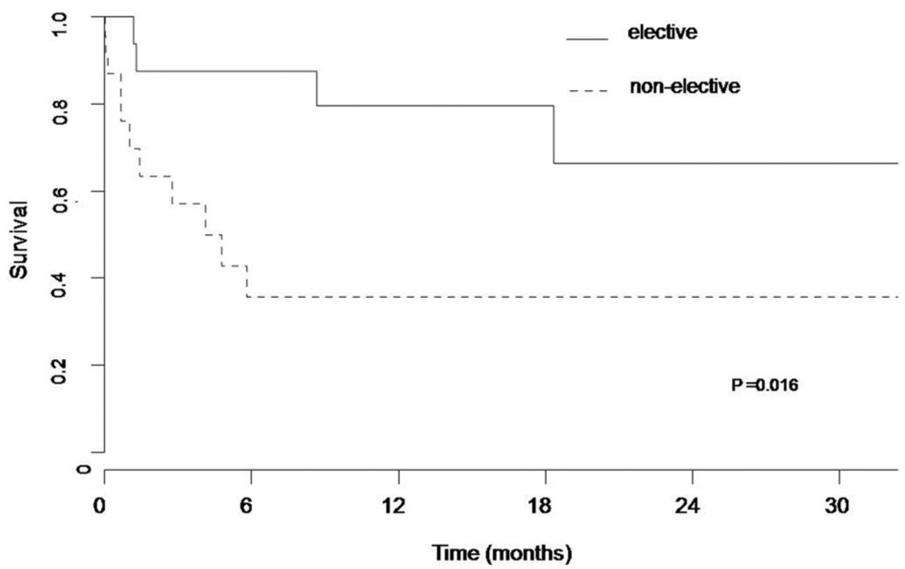
dence of reoperation was also noted with nonelective OCs (32% vs 0%; $P = .006$).

Mortality rates did not differ significantly between the elective (all of which were for aneurysm growth) and nonelective (5% vs 28%; $P = .11$) OC groups, but this was most likely related to the small number of patients. When evaluating for the indications of aneurysm growth and rupture, the difference in mortality rates between elective and nonelective OC for aneurysm growth or rupture closely approached statistical significance (5% [1 of 19] vs 29% [6 of 21]; $P = .05$); it was significant, however, when deaths after elective OC for aneurysm growth were compared with those after OC for rupture (5% [1 of 19] vs 33% [4 of 12]; $P = .038$).

Two patients underwent attempted endograft preservation but ultimately required graft explantation due to recurrent ruptures. The details of these patients and the lone intraoperative death can be found in the Appendix (online only).

Long-term follow-up

The mean survival after OC was 20 ± 24 months. Eight patients died during follow-up. One patient had partial explantation of a Zenith endograft for expanding aneurysm at age 90 years. He presented 20 months later with RAAA and was treated with bilateral iliac limb extensions to control distal type Ib endoleaks. He subsequently developed pneumonia, respiratory failure requiring a tracheostomy, and dialysis-dependent acute renal failure. He was finally transferred to hospice and died. Nine patients (20%) were lost to follow-up and no information could be found in the Social Security Death Index. Only one patient died among those treated with endograft preservation for aneurysm growth. Another patient in that group required endovas-



	Time (months)					
# at risk	**0**	**6**	**12**	**18**	**24**	**30**
Elective	**19**	**15**	**11**	**11**	**6**	**6**
Non-elective	**25**	**6**	**6**	**6**	**6**	**6**
Std. Error						
Elective		**0.08**	**0.11**	**0.11**	**0.15**	**0.15**
Non-elective		**0.12**	**0.12**	**0.12**	**0.12**	**0.12**

Fig 2. Kaplan-Meier estimate of survival after elective (*solid line*) and nonelective (*dashed line*) open conversions.

cular intervention after OC for realigning of the endograft. The remaining eight patients (80%) had complete follow-up, with imaging of the aneurysm confirming stability. Long-term survival was significantly higher after elective compared with nonelective OC (Fig 2).

DISCUSSION

This is the largest series of delayed OCs after EVAR reported in the literature and illustrates that OC of antecedent EVAR is accompanied by high complication and death rates, except for a select group of patients with aneurysm expansion who undergo ligation of feeding arteries for a type II endoleak with preservation of the endograft. Elective OC also provides an improved late survival. That one-third of OCs in this series took place ≥5 years after EVAR underscores the necessity for lifelong surveillance in these patients. Duplex imaging may substitute for CT if the aneurysm sac is shrinking or stable to reduce radiation exposure and contrast-induced nephrotoxicity.[9,10] Endoleaks may develop at any time, and no one is impervious to late complications of EVAR. As use of EVAR and its follow-up increase, the need for OC is likely to parallel the trend and underscore the need for close surveillance and timely OC when indicated.

The Achilles' heel of EVAR is its relatively high reintervention rate, which reached up to 28% after 8 years in the Comparison of Endovascular Aneurysm Repair with Open Repair in Patients with Abdominal Aortic Aneurysm (EVAR-1) trial.[11] Although most reinterventions were endovascular, 4% underwent OC with a 20% mortality rate, which is consistent with the results of the current study as well as those of other contemporary series with mortality rates of 17% to 25%.[5,12] The outcomes are worse when OC is required for an emergency situation, such as rupture. In the present study, 12 patients presented with rupture and underwent OC, with a 33% mortality. This is not dissimilar from what has been reported in the literature. Mehta et al[7] reported a 30-day mortality rate of 20% after OC in 15 patients with rupture. A Cleveland Clinic series reported a 67% mortality rate in six patients who presented with rupture.[5] Cho et al[13] showed that prior EVAR does not provide a survival advantage when the aneurysm ruptures.

This is in contrast to recent reports that suggested that OC after EVAR can be performed safely with low morbidity and no mortality, irrespective of acuity.[4,8] However, each study only had one patient who presented with rupture, and most OCs were elective. In the present study, only 43% of patients underwent elective OC, and the mortality rate in that subgroup was 5%, comparable to the perioperative mortality after primary elective open AAA repair.[1,3] It is evident that the literature on late OC after EVAR is difficult to interpret and the results are difficult to compare due to heterogeneous groups of patients with multiple mechanisms of endograft failure and varying presentations and indications for surgery. Nevertheless, nonelective OC appears to significantly increase the risks of morbidity.

In this series the mortality rate was 22% (2 of 9) after nonelective OC for aneurysm expansion, 28.6% (6 of 21) after nonelective OC for aneurysm growth or rupture, and 33% for rupture. These compare unfavorably with 5% for elective OC for aneurysm growth. This underscores the need not only for close surveillance but also the importance of timely OC for avoidance of nonelective conversion, especially rupture. It is well known that an increased risk of death is sustained even after successful repair of and discharge after RAAA repair,[14] and it was again noted in this series after nonelective OC. Avoidance of nonelective OC, hopefully with preservation of the endograft, is ideal to ensure optimal outcomes.

Management of endograft at the time of OC is a controversial subject. Late endograft removal may be technically challenging. The presence of barbs or hooks and/or suprarenal stents; additional stent graft, cuffs, or coils placed during secondary interventions; endograft-induced inflammatory changes around the vena cava; and the left renal vein and the iliac veins all elevate the complexity of the operation. Complete explantation may not be possible due to well-incorporated ends of endograft or may be hazardous. Complete excision of endograft may leave the aortic or arterial wall too thin and denuded, increasing the chance of anastomotic bleeding. In such cases, it is recommended to leave the well-incorporated endograft in place and to incorporate the adjacent arterial/aortic wall when suturing the surgical graft to the endograft remnant to prevent any subsequent type I endoleak.

Some investigators have advocated preservation of all or part of the endograft at the time of late OC to reduce morbidity and mortality rates.[6,15-17] The results in the present study support the notion of endograft preservation in the setting of sac expansion. Complete endograft preservation was achieved in 10 patients with aneurysm expansion in the present study without perioperative death and no rupture on follow-up; however, attempted preservation for RAAA in two patients was not fruitful.

It is intuitive that multiple attempts in the treatment of RAAA are undesirable. They are invariably accompanied by increased blood product transfusion requirements, increased length of hospital stay, other complications, and death. The two patients in the present study who presented with rupture and were initially treated with complete endograft preservation and ligation of back-bleeding arteries had poor outcomes. Both were readmitted with bleeding shortly after OC and eventually died. Exploration of patients with contained rupture likely makes identification of sources of bleeding and endotension more difficult due to hemodynamic disturbances that may mask type I or type II endoleak at the time of exploration. That may explain how the two patients with ruptures, who were treated with complete endograft preservation, were readmitted with rupture shortly after open ligation of back-bleeding arteries. Therefore, we caution against using compete endograft preservation in cases of rupture and would favor explantation of the endograft. All too often, the surgeons are given only one chance at it.

In the current study, although the actual rates of OC after EVAR have been relatively stable, the number of OCs seems to have increased over the study period as expected.[4,17] A tertiary referral center is more likely to witness such a trend, as we have. This trend is likely to continue because of the rising number of EVARs being performed, intrinsically high reintervention rates after EVAR, longer follow-up, and the proportion of EVARs that are performed outside of instruction for use.[18-20] Furthermore, with an increasing number of young patients aged between 50 and 64 years (the number doubled from 2001 to 2006) being treated by EVAR, the number of patients requiring OC for rupture and other endograft-related complications over a course of long-term follow-up is likely to contribute to this trend.[18]

The decision for OC has to be made after considering the entire clinical scenario such as the patient's comorbidities, life expectancy, the indication for conversion, and the extent of the prospective OC (ie, complete explantation vs lumbar ligation vs banding). Furthermore, identifying patients who are likely to develop late complications requiring OC is difficult. Thus, it would be inadvisable to set hard rules for OC. However, one should consider OC after failed endovascular interventions for continued yearly aneurysm growth of >5 mm on two consecutive imaging assessments or >6 cm on minor axis measurement. Any demonstrated or suspected type I endoleak should be treated if an endovascular solution is exhausted.

Even though this study presents the largest series of delayed OC after EVAR, the major limitations include the inherent selection bias of retrospective data collection and the relatively small number of patients, which hindered apparent differences from reaching significance. The patients with OC are a heterogeneous group with respect to indications and surgical techniques, making statistical analysis impossible after stratifying patients, as summarized in Tables II and IV. Furthermore, 20% of patients were lost to follow-up. This may underestimate late graft-related complication and mortality rates.

CONCLUSIONS

Late OC for graft-related or aneurysm-related complications after EVAR is associated with significant morbidity and mortality rates except when electively treating aneurysm expansion from an isolated type II endoleak with ligation of the feeding branches and preservation of the endograft. A strategy toward proper recognition of indications for OC and timely intervention is necessary to help improve both the short- and long-term outcomes of late conversion.

AUTHOR CONTRIBUTIONS

Conception and design: JC
Analysis and interpretation: IC, JC,

Data collection: IC, JC, RE, ET
Writing the article: IC, JC, GA
Critical revision of the article: IC, JC,
Final approval of the article: IC, JC
Statistical analysis: TP
Obtained funding: Not applicable
Overall responsibility: JC

REFERENCES

1. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeek MR, Balm R, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351: 1607-18.
2. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG, EVAR trial participants. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004;364:843–8.
3. Lederle FA, Freischlag JA, Kyriakides TC, Padberg FT Jr, Matsumura JS, Kohler TR, et al. Outcomes following endovascular vs open repair of abdominal aortic aneurysm: a randomized trial. JAMA 2009;302:1535-42.
4. Brinster CJ, Fairman RM, Woo EY, Wang GJ, Carpenter JP, Jackson BM. Late open conversion and explantation of abdominal aortic stent grafts. J Vasc Surg 2011;54:42-6.
5. Kelso RL, Lyden SP, Butler B, Greenberg RK, Eagleton MJ, Clair DG. Late conversion of aortic stent grafts. J Vasc Surg 2009;49:589-95.
6. Lipsitz EC, Ohki T, Veith FJ, Suggs WD, Wain RA, Rhee SJ, et al. Delayed open conversion following endovascular aortoiliac aneurysm repair: partial (or complete) endograft preservation as a useful adjunct. J Vasc Surg 2003;38:1191-8.
7. Mehta M, Paty PS, Roddy SP, Taggert JB, Sternbach Y, Kreienberg PB, et al. Treatment options for delayed AAA rupture following endovascular repair. J Vasc Surg 2011;53:14-20.
8. Gambardella I, Blair PH, McKinley A, Makar R, Collins A, Ellis PK et al. Successful delayed secondary open conversion after endovascular repair using partial explantation technique: a single-center experience. Ann Vasc Surg 2010;24:646-54.
9. Chaer RA, Gushchin A, Rhee R, Marone L, Cho JS, Leers S, et al. Duplex ultrasound as the sole long-term surveillance method post-endovascular aneurysm repair: a safe alternative for stable aneurysms. J Vasc Surg 2009;49:845-9.
10. Beeman BR, Doctor LM, Doerr K, McAfee-Bennett S, Dougherty MJ, Calligaro KD. Duplex ultrasound imaging alone is sufficient for mid-term endovascular aneurysm repair surveillance: a cost analysis study and prospective comparison with computed tomography scan. J Vasc Surg 2009;50:1019-24.
11. United Kingdom EVAR Trial Investigators, Greenhalgh RM, Brown LC, Powell JT, Thompson SG, Epstein D, et al. Endovascular versus open repair of abdominal aortic aneurysm. N Engl J Med 2010;362: 1863-71.
12. Millon A, Deelchand A, Feugier P, Chevalier JM, Favre JP, University Association for Research in Vascular Surgery (AURC). Conversion to open repair after endovascular aneurysm repair: causes and results. A French multicentric study. Eur J Vasc Endovasc Surg 2009;38:429–34.
13. Cho JS, Park T, Kim JY, Chaer RA, Rhee RY, Makaroun MS. Prior endovascular abdominal aortic aneurysm repair provides no survival benefits when the aneurysm ruptures. J Vasc Surg 2010;52:1127-34.
14. Barbato JE, Kim JY, Zenati M, Abu-Hamad G, Rhee RY, Makaroun MS et al. Contemporary results of open repair of ruptured descending thoracic and thoracoabdominal aortic aneurysms. J Vasc Surg 2007;45: 667-76.
15. Jimenez JC, Moore WS, Quinones-Baldrich WJ. Acute and chronic open conversion after endovascular aortic aneurysm repair: a 14-year review. J Vasc Surg 2007;46:642-7.
16. Mehta M, Paty PS, Roddy SP, Taggert JB, Sternbach Y, Kreienberg PB, et al. Treatment options for delayed AAA rupture following endovascular repair. J Vasc Surg 2011;53:14-20.
17. Nabi D, Murphy EH, Pak J, Zarins CK. Open surgical repair after failed endovascular aneurysm repair: is endograft removal necessary? J Vasc Surg 2009;50:714-21.
18. Schwarze ML, Shen Y, Hemmerich J, Dale W. Age-related trends in utilization and outcome of open and endovascular repair for abdominal aortic aneurysm in the United States, 2001-2006. J Vasc Surg 2009; 50:722-9.
19. Schanzer A, Greenberg RK, Hevelone N, Robinson WP, Eslami MH, Goldberg RJ, et al. Predictors of abdominal aortic aneurysm sac enlargement after endovascular repair. Circulation 2011;123:2848-55.
20. AbuRahma AF, Campbell J, Stone PA, Nanjundappa A, Jain A, Dean LS, et al. The correlation of aortic neck length to early and late outcomes in endovascular aneurysm repair patients. J Vasc Surg 2009; 50:738-48.

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Appendix (online only).

The intraoperative death occurred in an 82-year-old man who had undergone endovascular aneurysm repair (EVAR) at the age of 77 because he was deemed a prohibitive surgical candidate due to cardiac and pulmonary comorbidities. He had had three endovascular procedures for type Ia endoleak and a persistently growing aneurysm during a 5-year period before presenting with a ruptured abdominal aortic aneurysm (AAA).

The first procedure involved placement of an aortic cuff. In the second procedure, two Palmaz stents were used with partial coverage of the left renal artery. Because of persistent aneurysm growth, a chimney procedure was performed in which two aortic cuffs and a stent graft were placed into the left renal artery. The right renal artery, which supplied an atrophic kidney, was covered.

The patient presented with rupture 3 months after the last endovascular intervention. He had uncontrollable bleeding in the operating room and arrested. The intention of the surgeon was to completely explant the endograft; for that reason, the patient was classified with the complete explantation group. The other patients who died postoperatively had multiple complications and most required a return to the operating room to treat specific complications, as summarized in Table III.

Two patients underwent attempted endograft preservation but ultimately required graft explantation due to recurrent ruptures. The first was a 72-year-old man who presented with a rupture 30 months after the initial EVAR. Initially, the right internal iliac artery was ligated through a retroperitoneal approach. He presented again 1 month later with another rupture and underwent ligation of a lumbar artery and partial explantation of the right limb, which was replaced with a surgical graft. His postoperative course was prolonged and complicated by pneumonia and myocardial infarction; he needed a tracheostomy and a percutaneous feeding tube. He never fully recovered and died in a nursing home 7 months later.

The second patient was a 65-year-old man who presented 72 months after EVAR with a contained AAA rupture from a left iliac type I endoleak. He was first treated by coil embolization and extension of the left limb to the external iliac artery. He was discharged the next day, only to return 5 days later with a recurrent rupture with hemodynamic instability. He then underwent OC, during which a lumbar artery from within the aneurysm sac was ligated. The entire endograft was preserved. He was discharged to return home on postoperative day 13 but returned to the emergency department 7 days later with yet another episode of rupture. He then underwent a partial explantation of the endograft with aortoiliac reconstruction. This, however, was also complicated by further episodes of bleeding, requiring multiple open and endovascular interventions, and he died of multiorgan system failure.